TOWARDS AN UNDERSTANDING OF TALENT IDENTIFICATION IN ELITE SPORT

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ABSTRACT

The purpose of this thesis was to examine the efficacy of talent identification (TID) programs in predicting future success in elite-level sport. A systematic literature review was performed in phase 1 to synthesize the existing studies. Findings from this review highlighted a high degree of homogeneity in the samples and inconclusive outcomes for the variables examined. The objective of phase 2 was to discern whether testing variables employed by Golf Canada (GC) were effective in discriminating skilled from less-skill athletes. Findings revealed that their TID model does not hold discriminative or predictive utility. This thesis contributes to a limited literature base and provides direction for future research to enhance the selection process for elite-level athletes.

DEDICATION

For Dad

Brent Robinson
1942 - 2016

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CHAPTER ONE

General Introduction

Historical context of the research

In the context of sport, talent refers to a person's potential to achieve success. The process of identifying and developing one's potential through talent identification (TID) programs has occurred for many centuries. One of the first regimented systems was employed in ancient Greece (776 BCE approximately) where youth would train for admiration in events like wrestling (Baker, Cobley, Schorer, & Baker, 2013; Ghristopoulos, 2003). In the 1950s, the former German Democratic Republic and the Soviet bloc countries established elite sport development systems in order to stay competitive with neighbouring countries (Bloyce & Smith, 2009). In more recent decades, talent identification (TID) programs have received considerable attention and resources as they have been recognized for being critical pieces for achieving sport success (Brouwers, De Bosscher, & Sotiriadou, 2012; De Bosscher, De Knop, Van Bottenburg, & Shibli, 2006). Countries such as Australia, China, the United Kingdom, and the United States have been the driving nations of TID systems, acting as models for other countries to develop similar programs. Australia in particular has been recognized for its advancements in the development of the Australian Institute of Sport (AIS). After a poor performance at the Olympics in 1976, the nation implemented cutting-edge sport sciences to enhance athlete recognition and development (Baker et al., 2013). Despite considerable advancements in TID, a universally accepted TID model does not exist (Abbott & Collins, 2004; Louzada Maiorano, & Ara, 2016). In reality, decisions for athlete selection largely occur without a strong theoretical understanding, and are criticised as being fundamentally flawed (Abbott, Button, Pepping, & Collins, 2005; Régnier, Salmela, & Russell, 1993). For example, it is not uncommon for sporting organizations to make subjective decisions for player selection. Williams (2000) highlighted that high-level soccer clubs in the United Kingdom select players through the scout's recommendations on who displayed 'standout' performance. Similarly, Elferink-Gemser and colleagues (2007) drew attention to the need for athletes to 'convince' the coach, trainer or scout of their talent due to the subjectivity of the selection process in the Netherlands. In addition, Baker and colleagues (2013) noted that in Canada, it is common practice for athletes to attend 'try outs' where an athlete's selection is based on the performances of a series of tasks or drills that happen over a very short period of time. These examples draw attention to questionable decisions based predominantly on intuition rather than objective criteria.

In an effort to limit the subjectivity of the decisions, much of the recent research on sport expertise has been concerned with untangling the relative contributions of innate (nature) and learned (nurture) capacities on elite sporting performance (Davids & Baker, 2007; Hayman, Borkoles, Taylor, Hemmings, & Polman, 2014; Ericsson, Krampe, & Tesch-Römer, 1993; Lidor, Côté, & Hackfort 2009). This has been demonstrated in the increased interest regarding the role of genetics on talent acquisition (Breitbach, Tug, & Simon, 2014; Brutsaert & Parra, 2006; Davids & Baker, 2007; Tucker & Collins, 2016) and conversely, on the role of developmental experiences on the pathway to expertise (Ericsson, Krampe & Tesch-Römer, 1993; Helsen, Starkes, & Hodges, 1998; Ward, Hodges, Starkes, & Williams, 2007). While these research advancements have been integral in advancing our understanding of talent, little is understood about the optimal pathway to expertise and the many factors required for expert performance. In fact, it has been well documented that the existing literature is inconclusive with low predictive value (Barreiros, Côté & Fonseca, 2014; Bottoni, Gianfelici, & Tamburri, 2011).

Researchers have examined this dichotomy between theory and practice drawing attention to the large number of potentially talented athletes that are excluded from TID programs because of poor talent transfer and a high degree of talent wastage (Abbott & Collins, 2004; MacNamara & Collins, 2011; Tranckle & Cushion, 2006). This in turn, has the potential to negatively impact sport organizations, coaches and athletes. In particular, if athlete selection is compromised or missed, it can lead to decreased participation rates or even withdrawal from sport. This draws attention to the need for a working model of TID that places an emphasis on more objective or evidence-based identification for high-achieving athletes.

Present Study

In Sept 2015, Golf Canada (GC) approached our research team with the task of critically analyzing their TID system. GC, intent on improving Canada's international performance in golf, aimed to improve their selection process for elite golfers. This thesis provides a summary of work conducted so far on this project. The present study utilized a multi-step approach, divided into two separate phases. In order to gain a thorough understanding of what is known about TID systems, the first phase involved a systematic review of the literature. Phase 2 involved an analysis on five years of data from GC's TID system. The information gathered from phase 1 was then used to inform phase 2 in the future directions section.

There are three primary objectives of this thesis. 1) To gain a better understanding of what is known about this phenomenon by examining the research over the past 25 years in TID in elite-level sport. 2) To highlight the strengths and weaknesses of GC current TID system. 3) To present evidence for a more informed, practical and efficacious TID system for GC.

CHAPTER TWO

What predicts talent selection in sport?

A systematic review of 25 years of research

Summary

Talent identification (TID) programs are an integral part of the selection process for elite-level athletes. While many sport organizations utilize TID programs, there does not seem to be a clear set of variables that are consistently capable of predicting future success. This review aims to synthesize the research in TID in elite sport to gain a better understanding of what is known about this phenomenon. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were used to identify 20 articles that met the inclusion criteria. Reviewing these articles, there was a clear overrepresentation of studies a) examined physical profiles of athletes (60%), b) focused on male samples (65%), c) examined athletes under the age of 20 (75%) and d) published between the years of 2010 and 2015 (65%). Upon closer examination, there was a high degree of variability in the factors that were found to discriminate between skilled and less skilled individuals. Findings from this review highlight that little is known about TID in elite sport, which calls for a greater diversity in TID research for elite-level athletes.

Introduction

Talent identification (TID) programs are designed to identify young athletes with the potential for success in senior elite sport (Vaeyens, Güllich, Warr, & Philippaerts, 2009). In recent years, TID programs have grown in popularity and are seen as critical avenues to maximize athletes' potential to achieve success (Anshel & Lidor, 2012; Lidor, Côté, & Hackfort, 2005). This is especially true as pressures for nations to excel in sport at the international level are greater than ever. It is not uncommon to see nations investing millions of dollars towards developing evidence-based approaches to finding a competitive edge. This has been reflected by a surge in research conducted on understanding issues of talent identification and the development of sport expertise over the past two decades (Collings & Mellahi, 2009; Lewis & Heckman, 2006; Muller, Abernethy, Eid, McBean, & Rose, 2010; Nijs, Gallardo-Gallardo, Dries, & Sels, 2014; Swann, Moran, & Pigott, 2014; Williams & Ford, 2008).

It has been suggested that an effective TID program has the potential to detect talent early, which may act as a vital component to increasing a nation's chances at sporting success (Vaeyens et al., 2009). Anshel and Lidor (2012) suggested that TID programs facilitate the athlete selection process, thus maximizing the number of gifted individuals at both domestic and international levels. Similarly, Durand-Bush and Salmela (2001) noted that TID programs have the capacity to recognize talented athletes early, which helps to focus funding and training opportunities on athletes with the greatest potential for success. However, despite the potential advantages of TID programs, there remains a discrepancy between what is proposed in the research and what is observed in practice (Pankhurst, Collins, & MacNamara, 2013).

How one perceives talent and ability is important (Wattie & Baker, in press), generally reflecting one's perspective on whether exceptional performance is the result of biological or genetically constrained factors (i.e., nature) or the end product of experience and learning (i.e., nurture) (Baker, Bagats, Büsch, & Schorer, 2012; Coutinho, Mesquita, Fonseca, & De Martin-Silva, 2016; Davids & Baker, 2007; Howe, Davidson, & Sloboda, 1998). While most scientists agree that both factors are important, the nature versus nurture dichotomy continues to dominate popular discourse (e.g., Gladwell, 2008; Epstein, 2013). Regardless of whether the notion of talent is legitimate or not, misconceptions regarding what talent 'looks like' are widespread in high performance sport settings.

This lack of understanding regarding the contributions of nature and nurture have led to inconsistencies around the definitions of talent and thus how it might be identified. For instance, Brown (2002) described talent as a "special, natural ability" and a "capacity for achievement or success" while Howe and colleagues (1998) noted talent was "the likelihood of becoming exceptionally competent in certain fields depends on the presence or absence of inborn attributes variously labeled as talents or gifts" (p. 399). Conversely, Gagné (2000) described it as "possessions and use of untrained and spontaneously expressed natural abilities (called aptitudes or gifts) in at least one ability domain, to a degree that places a child among the top 10% of his or her age peers" (p. 67). As demonstrated in these examples, there is considerable variation in the definitions, ranging from a focus on innate abilities to outcomes resulting from training and experience.

The very nature of TID is centered on the measurement and subsequent comparison of characteristics that contribute to sport specific performance. In order to filter out less talented individuals, researchers often compare different age groups and skill levels in a cross-sectional design (Breitback, Tug, & Simon, 2014). This type of methodology is heavily rooted in assumptions that important characteristics of future success can be extrapolated from individuals' performance at one given point in time (Davids & Baker, 2007). This way of thinking, in its simplest form, implies talent is static as it ignores many important variables such as maturity and relative age effects (see Wattie, Schorer, & Baker, 2015). However, many of the qualities that distinguish top athletic performance in adults may not be apparent until late adolescence (Pearson, Naughton, & Torode, 2006; Vaeyens, Lenoir, Williams, & Philippaerts, 2008) and early performance is not strongly related with later success (Helsen, Baker, Michiels, Schorer, Van Winckle, & Williams, 2012). Importantly, because chronological age and biological maturity rarely progress at the same rate, children may be helped or hindered on performance tests due to their biological maturity, especially when compared to chronological age norms (Malina, Coelho-E-Silva, Figueiredo, Carling, & Beunen, 2012; Matthys, et al., 2013).

Despite the increase in research attention to TID and athlete development, evidence regarding the origins of high-level ability has been largely based on cross-sectional designs from unidimensional perspectives. This review aims to a) gain a better understanding of what is known about this phenomenon by examining research conducted over the past 25 years, and b) provide evidence-based suggestions to help guide decision making for future TID programs. A review such as this has the potential to improve a range of athlete outcomes in competitive sport by increasing the efficiency and accuracy of TID.

Methods

This review used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Statement guidelines (Moher, Liberati, Tetzlaff, & Altman, 2009) to examine the literature on TID in elite sport. A customized search was completed for studies assessing talent identification in elite-level athletes according to the PRISMA guidelines (Moher et al., 2009). The search strategy for identifying articles was broken down into three phases: Phase 1: a search of the electronic databases; Phase 2: a search using additional resources; and Phase 3: a collaboration with a panel of experts.

Phase 1 consisted of a search of two electronic databases, Web of Science and Sport Discus in the time period of January 1990 through July of 2015. Studies were identified using the following search terms: “expertise AND sport”, “talent identification AND sport”, and “giftedness AND sport”. Phase 2 consisted of a secondary search of external sources such as the references list of articles found in Phase 1, references in books, and additional website searches (e.g., Robertson, Burnett, & Cochrane, 2014). The final phase incorporated a panel of three experts who suggested articles that fit the inclusion criteria. After scanning the list of articles from phase 1 and 2, it became evident that the selected researchers were strong contributors to the body of literature in sport expertise. Upon completion of the three phases, the study’s author(s), title, and year of publication were recorded and articles were sorted to elimin3ate duplicates. From the list of unique entries, the publication’s title was read to discern whether the article was written in English and in the form of a complete, peer-reviewed journal article (i.e., ‘commentaries’ or ‘abstracts’ were not included). From this refined list, a more intensive assessment took place, which required obtaining the abstracts and the full-text articles. Studies were included in the final review if they contained the following:

i) Skilled Participants: Only studies examining athletes who fell into the category of ‘skilled’, ‘talented’, ‘elite’, or ‘expert’ were included in this review. For example, studies involving physical education in school or ‘open’ level sport teams were not included. The purpose of this stipulation was so the focus remained on ‘talented’ individuals to help understand and monitor the pathway to excellence.

ii) Time-Based Comparison: The study must have tracked changes in a performance-related variable over a period of at least 12 months. For example, a study including anthropometric and/or skill-based assessments over the course of a week would not meet this criterion, as significant changes in performance are unlikely.

iii) Between-Group Comparison: Studies must compare a minimum of two different skilled/ talented groups. For example, a study was not sufficient if it examined a developmental program for a group of all professional athletes.

iv) Removal of Grey Area Topics: Studies exploring birthplace effects, deliberate practice, genetic predispositions, handedness, long-term athlete development, or relative age effects were not included in this review. Although relevant for discussions of the notion of talent, each of these topics has a sufficient evidence-base for its own individual PRISMA-based analysis (and in some cases these reviews have already been done - see Cobley, Wattie, Baker, & McKenna, 2009).

Results

Phase 1 identified 1696 articles from the database searches using the key words listed above with an English language restriction imposed. An additional 422 articles were identified through external sources, and a final 22 were added from the panel of experts, totaling 444 articles through additional sources. After duplicates had been removed, there were a total of 1695 articles selected. If the title or the abstract included a ‘grey topic area’ or if the article was a ‘comment on’ or ‘review’ it was eliminated from the study. After reviewing the titles and abstracts, 1316 of these records were eliminated, leaving 399 studies identified for full-text assessment. After a thorough assessment, 379 articles were removed, as they did not include a longitudinal design, an elite sample of athletes, or a between-group comparison. This left a total of 20 articles that remained in the final study selection (refer to Figure 1 for a flow diagram of the PRISMA process).

Descriptive Results

Of the 20 articles included in the review, 19 (i.e., 95%) were published in the ten-year period between 2005 and 2015 (the remaining study was published in 2004). Furthermore, 75% (n=15) of the articles examined samples under the age of 20, studies with a sample under 10 years of age accounted for 15% (n=3), one study had a sample over the age of 20 (5%) and one remaining study (5%) did not specify the ages of the participants. The majority of the studies (n=13, i.e., 65%) examined a male only sample. Only 25% (n=5) of the studies examined a female only sample, and the remaining five studies used a combination of both male and female participants. The studies included in this review were nearly all from European countries (n=16), with two studies from Australia and the remaining two studies did not specify.

The terminology used by the researchers of the studies to describe the levels of selection is represented in Table 2. The terminology greatly varied with studies using the term elite (n=3), professional (n=3), selected (n=3), drafted (n=2), final selection (n=1), elite cadets (n=1), high division (n=1), national (n=1), phase 3 selected (n=1), senior (n=1), successful (n=1), survivor (n=1), and top world (n=1).

The sport that had the greatest representation was soccer (n=7) followed by gymnastics (n=3) and rugby league (n=3). The remaining studies included Australian Football (n=1), handball (n=1), field hockey (n=1), tennis (n=1), triathlon (n=1), and water polo (n=1). There was one additional article that incorporated multiple sports including volleyball, swimming, judo, and soccer (Barreiros, Côté, & Fonseca, 2012). For a full list of descriptive statistics, refer to Table 2.

The 20 studies included in this review were sub-divided into categories according to the variables they examined. The first category, *cognitive/psychological capabilities and player profiles*, included two studies by Van Yperen and colleagues (2009) and Vestberg and colleagues (2012). Van Yperen and colleagues (2009) found that number of siblings, ethnic origin, parental divorce, goal commitment, problem focused coping, and 'seeking social support' to be capable of discriminating between skill levels. Vesteberg and colleagues (2012) found that creativity, response inhibition, cognitive flexibility, visual scanning, number sequencing, and letter sequencing, were variables with discriminative capabilities.

The second category, *physical profile,* explored the anthropometric, physiological and/or sport-specific skills/ motor capabilities of the athletes. The majority of studies (n=12) were represented in this category and included Bottoni and colleagues (2011); di Cagno and colleagues (2014); Gil and colleagues (2007); Gil and colleagues (2014); Lidor and colleagues (2005); Pion and colleagues (2005); Pyne and colleagues (2005); Till and colleagues (2013), Till and colleagues (2015), Till and colleagues (in press); and Vandrope and colleagues (2012). Some of the variables found to discriminate between the most skilled athletes and the next-highest skill level were aerobic capacity (Gil et al., 2014; Pyne et al., 2005; Till et al., in press), age/maturation (Gil et al., 2014), agility (Gil et al., 2014; Lidor et al., 2005; Pyne et al., 2005), height (Gil et al., 2014), jump height (Pyne et al., 2005), long jump (Lidor et al., 2005), med ball throw (Gonaus & Müller, 2012; Lidor et al., 2005), push up (Pion et al., 2015), rope jump (Pion et al., 2015), sit and reach (Pion et al., 2015), sit up (Pion et al., 2015), sport-specific drills (di Cagno, et al., 2014; Lidor et al., 2005; Pion et al., 2015; Vandrope et al., 2012), and sprint speed (Gil et al., 2007; Gonaus & Müller, 2012; Lidor et al., 2005; Pion et al., 2015; Pyne et al., 2005).

The third category, *previous performance/experience,* examined variables relating to how prior performance and tournament rankings predicted future achievement. There were two studies in this category, Barreiros and colleagues (2014) and Brouwers and colleagues (2012). These variables were not found to discriminate between skill levels.

The remaining four (i.e., 20%) studies included a combination of the aforementioned categories and were therefore considered *mixed measurement* studies. Elferink-Gemser and colleagues (2007) examined a combination of anthropometric, physiological, sport-specific skill/ motor capabilities, tactical skill, and psychological variables. The variables that were found to discriminate skilled females from the less skilled females were sprint speed, slalom dribble (sport-specific skill), general tactics confidence, and motivation. The skilled male athletes were discriminated by the variables sprint speed, slalom dribble, general tactics, tactics when in possession, and tactics when not in possession. Falk and colleagues (2004) found swimming times and game intelligence to be positively correlated with higher performing athletes. Figueiredo and colleagues (2009) did not find test results capable of discriminating between the highest skill group and the next highest skill group. Lastly, Huijgen and colleagues (2013) found the Loughborough Soccer Passing Test (LSPT), a sport-specific soccer drill, capable of discriminating between skill levels.

Discussion

Overall, there were inconclusive findings from the studies included in this review. This was represented in the high degree of variability found in the efficacy of different variables to predict future attainment. While some studies found predictive variables capable of predicting future success (di Cagno et al., 2014; Falk et al., 2004; Pion et al., 2015; Van Yperen et al., 2009; Vestberg et al., 2012), others did not, and even questioned the efficacy of early identification in TID programs (Barreiros et al., 2014; Bottoni et al., 2011; Brouwers et al., 2012; Till et al., 2015).

In general, no variables within the studies examined uniformly predicted success. While some variables appeared multiple times in different studies (i.e., height, weight, maturity level, sprint tests, strength tests, and agility tests) there was no consistent relationship found between those variables and greater skill. For example, Pyne and colleagues (2005) found that anthropometric measures were not capable of discriminating between skill levels in Australian football, whereas Gil and colleagues (2007) found that anthropometric measures did discriminate between selected and non-selected soccer players.

Despite these discrepancies, there were some agreements between studies. For example, sprint abilities were found to successfully discriminate between skill levels in eight of the studies (Figueiredo et al., 2009; Gil et al., 2007; Gonaus & Müller, 2012; Lidor et al., 2005; Pion et al., 2015; Pyne et al., 2005; Till et al., 2015; Till et al., in press). In addition, agility drills were successfully used to discriminate between skill levels (Figueiredo et al., 2009; Gil et al., 2014; Lidor et al., 2005; Pyne et al., 2005; Till et al., 2015; Till et al., in press). Furthermore, three studies examining gymnasts demonstrated successful discrimination between skill levels with the KörperkoordinationsTest für Kinder (KTK) test which is a representation of coordination and precision of young gymnasts (di Cagno et al., 2014; Pion et al., 2015; Vandrope et al., 2012). Furthermore, there was some consistency in variables that did not predict future attainment. Barreiros et al., (2014) and Brouwers et al., (2012) found no evidence that previous performance/ attainment was predictive of future success. Additionally, measures of body composition, as reflected in body mass index (BMI), sum of skin folds or body fat percentage, were used in a number of studies, (Figueiredo et al., 2009; Gil et al., 2007; Gil et al., 2014; Pion et al., 2015; Pyne et al., 2005; Till et al., 2013; Vandrope et al., 2012), however none found a significant relationship.

Moving Forward: Future Research Directions in TID

In addition to providing a review of what is a surprisingly limited literature base on TID in sport, this review is important for highlighting key areas of future research. For example, the lack of consistency in the terminology used to express skill levels made it challenging to draw inferences between samples. For example, in this present review, the terms ‘elite’, ‘professional’, ‘selected’, ‘national’, and ‘drafted’ were all used to classify skilled participants (refer to Table 2 for full list of terminology). It is important to note that even small variations in the way talent is defined may greatly affect how it might be identified, measured and developed. This finding is not an isolated one as previous research in sporting expertise has highlighted the inconsistencies in the terminology and taxonomy of skill levels (Baker, Wattie, & Schorer, 2015). Swann and colleagues (2014) found that ‘expert’ athletes could refer to an athlete who is performing at an international level or to an athlete who is performing at a collegiate level. To help categorize skill levels, Baker and colleagues (2015) proposed a taxonomy of sport-skill levels to provide a system for more accurately classifying skill across sport domains. It will be important for researchers moving forward to utilize a definition that is consistent and appropriate for the taxonomy of skill level to gain a better understanding about the pathways to excellence.

The need for more diverse research

Perhaps most significantly, the results from the present review highlight the need for a greater diversity in TID research for elite-level athletes. One example can be seen in the significant imbalance between the representation of male (65%), female (10%), and mixed participant (25%) samples. Despite our general conclusion that we know very little about predictors of talent in elite sport, we know even less about predicting talent in female athletes. Given the often unique development systems for high performance female athletes, this discrepancy might limit our ability to gain a deeper understanding of talent, and as a result, may lead to potentially harmful consequences for the female athlete population. Furthermore, the fact that only three sports (soccer, gymnastics and rugby league) were represented more than once in this review speaks to how little we know about the vast majority of sports. This lack of diversity makes it very difficult to draw inferences about the predictive utility of testing variables. It also makes it very challenging to isolate a variable that could act as a robust indicator across sport domains.

Not surprisingly, there was an overrepresentation of studies published in the past decade (i.e., 19 out of 20) where 65% of those studies were published in the past five years. This implies we know very little about the longitudinal nature of TID programs and for this reason, precautions should be taken when basing future decisions on previous research. While there are notable drawbacks of conducting longitudinal studies (time and financial constraints), in the long-term, the advantages of obtaining longitudinal data outweigh these drawbacks. This may be especially true as this review highlights the deficit in longitudinal studies examining elite athletes in TID programs (e.g., the number of articles identified in the initial search versus the final selection).

It was surprising to see that the majority of the studies in this review were from European nations with the remaining three studies from Australia. This, once again, emphasizes the need for more diverse research internationally, particularly in countries like the United States and the United Kingdom, where talent identification is an established element of their athlete development programs.

Another example of how little is known about TID in elite sport can be seen in the lack of diversity in number of studies that examined athletes that were under the age of 10. As demonstrated in Table 2, there is an overrepresentation (i.e., 75%) of studies that examine athletes under the age of 20 (n=15), with only 15% (n=3) of studies looking at athletes under the age of 10 and only one study looking at athletes over the age of 20. This speaks to the fact that we know very little about how to effectively identify younger athletes, especially when it has been documented that most of the research on TID involves athletes during their adolescent years (Breitbach, et al., 2014). While this can be viewed as an advantage for sport organizations that seek early identification, it also presents some negative consequences. Early identification typically occurs during the maturation process when testing measures are the least stable (Pearson, et al., 2006). This is especially detrimental as there is evidence to support that TID is happening even before an athlete reaches puberty (Bloom & Sosniak, 1985). This instability is thought to be a result of the large variation in growth potential in the physical and physiological predictors during the time of testing (Breitback et al., 2014; Pearson, et al., 2006). In their review, Pearson and colleagues (2006) draw attention to the impact that maturity has on testing parameters such as height (Baxter-Jones & Helms, 1996), weight (Roemmich & Rogol, 1995), body composition (Roemmich & Rogol, 1995; Beunen, Malina, Lefevre, Classens, & Renson, 1997; Herman-Giddens, Wang, & Koch, 2001), anaerobic capacity (Inbar & Bar-Or, 1986), and strength (Hansen, Bangsbo, Twisk, & Klausen, 1999). All of these parameters are affected by stage and rate of maturation, which makes finding a true value of predictive success very difficult in TID programs with adolescent athletes. While there is some evidence demonstrating the changes in physical and physiological variables during maturation, we know very little about the stability of cognitive and psychological factors and how they adapt during the early years of an athlete's life. It will be important for future research to focus on these factors in order to enhance the effectiveness of early TID.

The need for a more ecological design

Some (Pinder, Renshaw, & Davids, 2013; Unnuthan, White, Georgiou, Iga & Dust, 2012) have suggested that a contributing reason why TID programs are not effective in identifying, selecting and developing talented athletes is due to the reductionist tendency to deconstruct performance tasks into smaller sub-phases, which are then used as testing measures in TID programs. This was demonstrated in a number of studies that attempted to isolate the parameters of the sport specific demands with a simplified agility drill within a sport that is dynamic and interactive like soccer (Figueiredo et al., 2009; Gil et al., 2014; Gonaus & Müller, 2012) handball (Lidor et al., 2005), Australian football (Pyne et al., 2005) and rugby league (Till et al., 2013; 2015; in press). As this method does not appear to be effective in representing the demands of competition, it has been suggested that there should be a shift away from this line of thinking in future research (Vaeyens, et al., 2009). Researchers have also proposed the need for a model that is more representative of performance demands, such as the Ecological Dynamics model (Davids, Araujo, Vilar, Renshaw, & Pinder, 2013; Pinder, Davids, Renshaw, Araujo, 2011). This model places an emphasis on the interactions of the individual in his/her environment where intentions, perceptions, and actions are interconnected rather than treated as separate entities. It will be important to consider this model when trying to account for inter-individual differences in future research.

It has been well documented that sport is multidimensional in nature, where the optimization of both physical and mental factors are required for elite performance (MacNamara, Button, & Collins 2010a, 2010b; Vaeyens et al., 2008). Despite this, TID research has typically adopted either a unidimensional approach or a restrictive approach by focusing on a select few dimensions of variables (irrespective of known theoretical frameworks) (Abbott & Collins, 2004; Grove, 2001; Hoare & Warr, 2000; Staerck, 2003; Vaeyens et al., 2008). This approach largely ignores other factors that could influence performance. In particular, there is significant literature highlighting the central role that psychological factors (e.g., coping skills, resilience, confidence, cognitive strategies, determination) play in elite performance (e.g., Abbott & Collins, 2004; Durand-Bush & Salmela, 2002; Gould & Maynard, 2009; MacNamara, Button, & Collins, 2010a; MacNamara & Collins, 2015; Phillips, Davids, Renshaw, & Portus, 2010) and how these psychological skills can be incorporated into TID programs (e.g., Abbott, Collins, Sowerby, & Martindale, 2007; MacNamara et al., 2010a, 2010b; Van Yperen, 2009).

This underrepresentation of multidimensional designs was reflected in the current review, where there was an overrepresentation of studies examining the physical profiles of athletes in TID systems. From the final selection of studies, 60% of the studies focused on physical variables. While many of these studies had test batteries that were quite extensive, they may have been limited by the absence of important psychological and environmental factors (Baker & Horton, 2004; Côté, 1999; Pion et al., 2015). There were, however, four studies that embraced the multidimensional approach (in the *mixed* *measurement* category) and examined a combination of physical, physiological and psychological measures. It was likely no coincidence that all four of these studies (Elferink-Gemser et al., 2007; Falk et al., 2004; Figueiredo et al., 2009; Huijgen et al., 2013), found some predictive utility in the testing variables. This finding echoes the recommendations from Abbott and Collins (2004), and speaks to the importance of utilizing a multidimensional approach to allow for a more representative testing design. It is with this hope that a more representative and ecological model will be used to increase the chance of finding variables that hold predictive utility for elite-level athletes.

Limitations of the review

Although this systematic review provides the first comprehensive synthesis of existing work on predictors of talent in elite sport, it is not without its limitations. One of the main limitations lies in the exclusion of articles that were listed in the 'grey area' (birthplace effect, deliberate practice, genetic predispositions, handedness, long term athlete development relative age effect). While the inclusion of these studies would likely enhance the understanding of TID in elite sport, the sheer number of articles would have been too difficult to synthesize in a single review. For example, there were an estimated 34 articles examining relative age effects along with an additional 30 articles examining deliberate practice that would have met our criteria.

An additional limitation lies in the restriction imposed on articles written in English and coming from peer-reviewed journals. It is likely that these restrictions only offered a fraction of the published articles on TID in elite sport.

Practical Application

To our knowledge, this is the first systematic review on the efficacy of TID programs in predicting successful performance in skilled athletes. The findings of this study have many positive implications to the field of research. Primarily, this study provides a comprehensive synthesis of the past 25 years of research and draws attention to the many gaps in the current body of research.

Furthermore, this research has the potential to inform coaches, athletes and other sport stakeholders about the importance of choosing testing variables that are based on evidence and current theory. This review also has the potential to encourage sport organizations that are currently employing unidimensional TID systems to critically analyze their system and consider incorporating a more multidimensional design. This may in turn, decrease the amount of talent wastage and decrease the risk of wrongfully de-selecting a potentially talented individual.

Conclusion

This review aimed to synthesize and analyze the past 25 years of research on TID in elite-level sport. Overwhelmingly, findings from this review revealed inconsistent and unreliable predictors and demonstrated a fairly homogenous body of research on TID in elite-level sport. Collectively, it seems reasonable to conclude that there remains a substantial amount of information that we have yet to learn in this field and that future work should reflect a greater diversity in study designs (e.g., variables, samples, etc.) to reflect the considerable diversity in high performance sport.

CHAPTER THREE

Talent selection in golf:

Towards a more representative design

Summary

With increased pressure from nations to excel in sport at the international level, there is growing pressure for sport organizations to implement effective talent identification (TID) programs. Despite a growth in TID research for elite-level athletes in recent years, there does not appear to be a universally accepted TID program that is efficacious in predicting future success. In fact, traditional TID systems are criticized for excluding potentially elite-level athletes due to inappropriate selection of testing measures. Therefore, the objective of the present study was to analyze an elite-level TID program to discern whether the testing variables were effective in discriminating skilled from less-skill athletes. To this end, an exploratory analysis was conducted on a longitudinal database collected by Golf Canada (GC). Findings revealed that the TID model currently employed by GC does not hold discriminative or predictive utility. This is likely a result of inconsistent data entry as well as the unidimensional nature of the testing design. These findings illuminate the need for a more evidenced-based approach to enhance the validity of the current TID model used to select elite-level golfers.

Introduction

Recent research has aimed to identify the factors and developmental pathways leading to elite-level performance (Côté, Baker, Abernethy, 2007; Côté, Lidor, & Hackfort, 2009; Ericsson, 2007; Ford, Ward, Hodges, & Williams, 2009; Fransen, Pion, Vandendriessche, Vandrope, Lenoir, & Philippaerts, 2012; Hayman, Polman, Taylor, Hemmings, & Barkoles, 2011; Hayman, Borkoles, Taylor, Hemmings, & Polman, 2014). It is hoped that through these explorations that factors underpinning talent acquisition will surface, thus allowing for a means to accurately identify and predict talented individuals. This talent identification (TID) process is becoming increasingly more attractive to sport organizations as a greater emphasis is placed on early identification and selection of young athletes (Abbott & Collins, 2004; Falk, Lidor, Lander, & Lang, 2004). Countries like Australia, Canada, China, the United Kingdom, and the United States have allocated significant resources to the development of evidence-based TID programs. While this has led to advancements in the quantity and quality of research and practice, coaches are still selecting athletes on what they believe talent 'looks' like without a strong theoretical basis for decisions (Baker, Cobley & Schorer, 2013; Elferink-Gemser, Visscher, Lemmink, & Mulder; Williams; 2000)

It is widely accepted that talent is a complex phenomenon (Abbott & Collins, 2004; Breitbach, Tug & Simon, 2014; Loland, 2015;Vaeyens, Lenior, Williams, & Philippaerts, 2008). This is seen in the multitude of factors that have been reported to affect talent development, including variables such as motor skills (di Cagno et al., 2014; Falk et al., 2004; Figueiredo, Goncalves, Coelho-E-Silva, & Malina, 2009; Huijgen, Elferink-Gemser, & Visscher, 2013; psychological capacities (Van Yperen, 2009;

Vestberg, Gustafson, Maurex, Ingvar, & Petrovic, 2012), physiological skills (Elfereink-Gemser et al., 2007; Gil et al., 2014; Gonaus & Muller, 2012; Pion, Lenoir, Vandrope, & Segers 2015; Till, Cobley, O'Hara, Chapman, & Cooke, 2013; Pyne, Garder, Sheehan, & Hopkins, 2005), anthropometrical profiles (Gil et al., 2007; Lidor et al., 2005; Pion et al., 2015), environmental support (Côté, 1999; Durand-Bush & Salmela, 2002; Gould, Dieffenbach, & Moffett, 2002; Hayman et al., 2011; Keegan, Harwood, Spray, & Lavellee, 2010; Vernacchia, McGuire, Reardon, & Templin, 2000), perceptual-cognitive skills (Fischer, Reinhoff, Tirp, Baker, Strauss, & Schorer, 2015; Lidor, Falk, Arnon et al., 2005; Martell & Vickers, 2004; Nideffer, Sagal, Lowry, & Bond, 2001; Singer, 2000, Vickers, & Williams, 2007), and genetic factors (Davids & Baker, 2007; Maciejewska-Karlowska, Hanson, Sawczuk, Cieszczyk, & Eynon, 2014). Furthermore, while these factors play a role, the degree to which they influence talent acquisition and how they can be effectively measured, remains unclear.

Moreover, what we do know about talent seems restricted to a few sports from a small number of countries. For instance, there has been a heavy emphasis on soccer (Meylan, Cronin, Oliver, & Hughes 2010; Morris, 2000; Reilly, Williams, Nevill & Franks, 2000; Rahnama, 2010; Robinson, Wattie, Schorer, & Baker, in review; Vaeyens, Lenior, Williams & Pilippaerts, 2008; Williams, 2000) and very little exploration of other sports. In this investigation we explore talent development in golf, a sport that remains underrepresented in the talent development and skill acquisition literature (for exceptions see Hayman et al., 2011; Hayman et al., 2014; Robertson, Burnette, Gupta, 2014; Robertson, Gupta, Kremer, et al., 2015; Swann, Keegan, Crust, & Piggott, 2016).

Golf is a unique sport that can be played by individuals of many ages and skill levels (Hayman et al., 2014; Hayslip, Petrie, MacIntire, & Jones 2010). It has also been described as a demanding and diverse game that requires precision, physical strength and power (Wells, Elmi, & Thomas, 2009). For example, a typical male golfer can perform a swing that translates 900kg of force to the ball during one shot, while needing to lightly tap the ball to execute subsequent shots (Wells, et al., 2009). In addition to the physical and physiological demands, golf is also known as a game of cognitive processing and mental strength (Hayslip et al., 2010; Wells et al., 2009). For instance, psychological skills such as engaging in self-talk, employing pre-shot routines, disregarding feelings of stress, and using imagery have been shown to be positive behaviours in developing expertise (Hayslip et al., 2010; Murphy 1994; Ryska, 1998). The present study aimed to contribute to this growing literature base by examining the TID used in elite level golf. Through a collaborative partnership with Golf Canada (GC), we were able to evaluate data collected longitudinally through their TID and development system to determine whether their testing measures were able to discriminate between more and less-successful athletes. This analysis will be helpful for highlighting strengths and weaknesses of the current system and suggesting ways GC could enhance their TID program.

Methods

Procedure

This study involved the evaluation of a dataset from GC that included testing results from 2010 to 2015 for 50 athletes. This group consisted of 26 male (mean age

21.2 SD 2.6) and 24 female golfers (mean age 19.9 SD 2.8) who were selected to the Team Canada development program. A total of 206 variables were noted in the database, however 35 of these variables listed were not actively measured during the testing periods and thus, were eliminated from the analysis (refer to Table 4). A remaining 146 variables were also excluded due to low statistical power (data collected on less than 4% of the sample). The remaining 25 variables were used for analyses (see Table3). For a full description of the categories see Table 5 and their composite variables see Table 4 and Appendix A.

Statistical Analyses

Basic descriptive statistics were calculated for all 50 athletes. Round Score was identified as the most appropriate dependent variable as it was the outcome with the greatest player representation (n=39) over the course of the testing period. Due to inconsistencies in the number of rounds reported across tournament play (e.g., only the strongest players make the 'cut' for advanced rounds), only scores from the first two rounds were used. Athletes with a lower average round score were considered more skilled in comparison to athletes with a higher average round score.

An exploratory approach was taken for analyzing the data. Due to the lack of data in the categories *Trackman Combine, Flight Scope,* and *SAM Puttlab*, these variables were not considered for analysis. The *Physical Testing-Jason Glass* category of variables was also not considered due to the subjectivity of the testing measures. Separate multiple linear regressions were performed for variables in the *Trackman, Physical Testing, Handicap and World Ranking, Beep Test* and *Tournament Ranking* categories. Further, to determine which of the range of variables might best predict round score, a backwards-stepwise regression was performed with those variables that had sufficient data to be analyzed. Alpha was set at $p < .05$ and all analyses were performed using SPSS version 22.

Results

Descriptive statistics revealed that all the measures included in the test battery examined the golfers' physical profiles. Figure 1 demonstrates that 45% of variables examined the golfers' motor skills, another 40% examined physiological factors, an additional 9% provided a ranking measure of performance and the remaining 6% explored anthropometric variables.

Analysis of the data revealed that there was no variable found in the GC TID program that statistically discriminated between more skilled and less-skilled athletes. More specifically, results of the multiple linear regression performed on the variables in the *Trackman, Handicap and World Ranking, Beep Test* and *Tournament Ranking* categories, revealed no significant correlations with average round score.

In the *Physical Testing* category, bilateral squat jump and push up were significantly associated with average round score (with beta values of -0.54 and -0.92 respectively). However, after controlling for sex in the backwards-linear regression these significant effects disappeared.

Discussion

The primary objective of this analysis was to better understand the efficacy of the testing battery utilized by GC in their TID program. An exploratory analysis revealed that none of the variables in the dataset was strongly associated with golf performance. However, it seems clear that the dataset did not contain sufficient consistent, reliable, and longitudinal data to make definitive decisions on what variables discriminate skilled golfers from less-skilled golfers. While GC has implemented a fairly extensive list of testing variables (206), there were only 25 variables (15%) that were appropriate for analyses. Even within those 25 variables, there were only three variables (squat jump, world ranking, and ball speed) that were represented by over half the sample of athletes. This degree of missing data acted as a considerable obstacle for conducting parametric tests and drawing inferences on the greater sample of athletes.

It is likely that the magnitude of missing data was partially a result of logistical limitations. With such an expansive dataset, it is difficult to obtain consistent data for each player. It is also likely that due to the nature of some of the tests involving technical equipment (SAM Puttlab, Trackman, Trackman Combine, and Flight Scope), the ability to conduct the test was limited. Moreover, variability in when athletes joined the GC program created unequal amounts of testing data for each player. For example, athlete number 42 only had testing data from 2014 and onwards making it difficult to compare results between athletes with four years of testing data.

Despite the lack of significance found within the current dataset, there has been previous research identifying positive correlations between anthropometrical, physiological and motor skill abilities, and skill levels. For example, Keogh and colleagues (2009) discovered that longer arm length was able to differentiate elite and sub-elite golfers. Additionally, Kawashima and colleagues (2003) found that professional golfers resembled a profile that was heavier, with greater amounts of fat free mass and larger limb girths. As well, measures such as greater physical strength (Sprigings & Neal, 2000), increased range of motion (Chettle & Neal, 2001), and greater club head speeds (Keogh, Marnewick, Maulder, Nortje, Hume, & Bradshaw, 2009) have also been found to be significantly correlated with skilled performance in golf.

Results from this present study highlight the unidimensional nature of the testing variables. As demonstrated in Figure 4, all the testing measures employed by GC examined the physical profile of elite golfers. This finding is consistent within the literature, as research on TID in elite sport tends to adopt a narrow focus of testing measurements, primarily targeting the physical profiles of athletes (Robinson, Wattie, Schorer & Baker, in review). This unidimensional approach has been criticized within the literature for ignoring many of the fundamental elements of elite performance, which will further be explored (Abbott & Collins, 2004; Hoare & Warr, 2000; Staerck, 2003; Vaeyens et al., 2008). It has also been suggested that this narrow focus is likely a contributing factor to low predictive values in TID programs (Abbott & Collins, 2002; Martindale, Collins, & Daubney, 2005).

It will be important for GC to consider the incorporation of a more multidimensional design as studies support the use of psychological capacities as well as developmental histories to discriminate between skill levels in golfers. McCaffrey and Orlick (1989) recognized that professional golfers had stronger practices of mental preparation, goal setting, imagery use, and focusing abilities, than non-professional golfers. More recently, Clark and colleagues (2005) noted that competitive golfers require strategies to manage thoughts, emotions and doubts between shots.

Research exploring the developmental histories of elite-level golfers through retrospective designs has suggested that expert golfers did not partake in early specialization but rather participated in a variety of different sports until the age of 16 (Hayman et al., 2011). Additionally, the influence of family has potential to play a role in the development of skilled golf performance. For instance, Hayman and colleagues (2014) recognized that the fathers of elite amateur golfers acted as primary initiators and long-term motivators (Hayman et al., 2014). It was also discovered that the role of the mother became increasingly more important as the golfers began to specialize in the sport (Hayman et al., 2014). These examples stress the importance of incorporating a more diverse set of testing measures. It is possible with the inclusion of a more diverse test battery that a more accurate representation of what comprises an elite-level golfer will be illuminated.

Limitations

Given the difficulty in accessing very elite samples of high performance athletes, the use of longitudinal data on high performance golfers in Canada is a strength of this study. However, the analysis was not without limitations. One of the most obvious lies with the quality of the dataset. A lack of consistent and longitudinal data made it very challenging to establish a measure of success. For example, ‘World Ranking’ would have been a preferred dependent variable in comparison to ‘Average Tournament Score’, however, due to a lack of consistent data for players, this was not be a reliable and valid variable to use. It also presented a challenge when the researchers were attempting to run an analysis with statistical power. This was reflected in the small number of testing variables (n=25) that were deemed useable from a list of 206 variables recorded.

Another prominent limitation lies within the nature of the secondary analysis conducted on the data. The study would have likely been enhanced if the researchers were able to cross-reference or extend our understanding of skill by having the coaches identify who they perceived the ‘skilled’ or most ‘talented’ athletes to be. This may have increased the validity of using the average round score as the measure of success and/or provided an additional measure of coaches’ perceptions of talent and skill.

Practical Implications

The findings of this investigation provide a unique examination of the variables used in the selection process of elite-level golf athletes. To the best of our knowledge, this is the first study to describe the testing data that is used by GC in their TID program. While there have been studies examining the profiles of elite Canadian golfers (Wells et al., 2009), the novelty of this study lies within the methodology used to critically analyze GC’s TID program. One of the most unique elements of this study is the potential to directly inform practice with the findings and future directions of this study. The researchers had a chance to speak with GC delegates and present the preliminary findings, which appeared to spark interest in future collaborative work between the researchers and GC. The researchers intend to stay involved with GC to help shape the

TID system to better identify and develop future talented golfers to represent Canada on an international scale.

This research study is timely, as pressures to create and implement effective TID programs for elite-level golfers are greater than ever (Hayman et al., 2014). It has been suggested that a potential catalyst for this growth in research and practice is the addition of Golf to the Olympic games in 2016 (Hayman et al., 2014). It can be suspected that the need for a more reliable and valid TID model for elite-level golfers will be of great importance to sporting organizations in the years to come.

Future Direction

It is Golf Canada's mission to produce the best amateur golfers in the world (Golf Canada, 2016). It is evident from their willingness to collaborate with the researchers in the present study that they strive to stay current and competitive on the international scale. The future directions in this section present evidence-based suggestions for GC to enhance their TID program. These suggestions will aim to increase the efficiency, resourcefulness and validity in their current selection process.

Increase consistency in data collection

In an effort to enhance the strength and quality of the data, it should become a priority for GC to collect consistent data on all Team Canada golfers. The researchers suggest that GC should select fewer variables and collect data more frequently in comparison to their present approach. By collecting more consistent data on a larger percentage of the sample, a more accurate analysis can be completed. This in turn should allow for stronger evidence regarding the unique pathways that athletes take to achieve excellence in golf.

Diversify testing measures to incorporate a more multidimensional design

It has been suggested that golf performance may be less reliant on the biological systems and more reliant on acquired skills (Baker, Horton, Pearce, & Deakin, 2006; Keogh et al., 2009). In response to this finding, GC should explore the most critical skills related to golf in order to create a more representative task design. For example, putting can account for nearly 40% of the shots taken in a single round of golf (Fearing, Acimovic, & Graves, 2011; Karlsen, Smith, & Nilsson, 2008). It therefore may be of interest to further isolate the parameters of putting (in addition to the SAM Puttlab variables) in order to capture the interactive and dynamic nature of the skill.

While it appears that many sport organizations utilize similar testing batteries, it may become advantageous for GC to explore variables such as intrapersonal factors like perseverance, resiliency/grit, personality, motivation, and self-regulation, emotional regulation and imagery (For more information on support in the literature, see Table 6). There is also growing support for the role of training- related variables such as the amount of deliberate play, number of training hours, prior coaching influences, and performance related milestones (see Table 6). In addition, environmental factors have been shown to have an influence on expert performance such as birthdate, birthplace, and support of the family. As well, the role of perceptual-cognitive skills such as quiet eye/ gaze characteristics, reading the game, decision making, and game intelligence. It can therefore be suggested that GC include a more multidimensional approach to selecting the testing battery. A guide to future directions on how to implement these measures with valid testing tools can also be found in Table 6.

Incorporate a between-group comparison

It will be helpful for GC to incorporate a between group-comparison in their study design. This will offer a better understanding into the causal relationship between factors affecting performance and achieving excellence in golf (Abernethy, Farrow, & Berry, 2003; Baker & Young, 2014). The inclusion of the testing data for those who are de-selected may be a useful place to start and might also provide important data regarding predictors of dropout or withdrawal from golf.

Conclusions

Overall, the findings highlighted the limitations associated with the considerable missing and inconsistent data. As a result, it appears as if the testing battery employed by GC was not effective in discriminating between more successful (lower average round score) and less-successful golfers (higher average round score). In order to help inform a more effective process in the future, this study highlighted the limitations of the current model and presented potential avenues in the form of evidenced-based suggestions to enhance the current TID model. It was encouraged that GC collect more consistent and longitudinal data, along with the implementation of a more multidimensional testing battery that is more representative of competition demands. It is hoped that this research will not only inform and equip GC, but also guide future decisions on athlete selection in other sports.

CHAPTER FOUR:

General Discussion

Summary of the research project

The two studies included in this research project provide important insight into the quality and quantity of research on TID in elite-level sport. While both aimed to identify 'best practice' strategies in TID systems, neither provided strong evidence in support of TID programs as an effective tool to enhance athlete selection.

The findings from the systematic review highlighted the limited number of articles examining the factors that predict future excellence. While 1696 articles were initially identified, only 20 met the inclusion criteria for the review. These studies illustrated an overrepresentation of research on male samples under the age of 20, as well as an overrepresentation of studies examining the physical profiles of elite-level athletes. While some studies (di Cagno et al., 2014; Elferink-Gemser et al., 2007; Falk et al., 2004 Gil et al., 2014; Gonaus & Müller, 2012; Lidor et al., 2005; Pion et al., 2015; Pyne et al., 2005; Vandrope et al., 2012; Van Yperen et al., 2009; Vestberg et al., 2012) identified variables that discriminated between eventual skill levels of athletes, a consistent predictor was not identified within the studies.

In the second study, an analysis of GC's testing data revealed similar findings to those in the first study. Despite the inclusion of a very expansive testing battery (206 variables), variables holding discriminative or predictive utility were not identified. Findings also revealed that, similar to study 1, there was overrepresentation of testing variables that focused on physical qualities.

Implications for theory and practice

It is possible that one of the main reasons a predictive indicator in TID programs remains elusive is due to a lack of understanding of what talent is, and how it can be reliably measured. Disagreement remains in the literature over whether talent is the result of biological and genetic, cultural, or environmental factors (or any combination of the three), which creates a challenge for making sound theoretical decisions. Until a solution outlining the components that contribute to expert performance is determined (if one in fact exists), effectively measuring talent in an athlete selection program will be an ongoing challenge. This challenge is not only unique to the sport domain, but in music (Haroutounian, 2000; Howe et al., 1998) and education (Esters, Ittenbach & Han, 1997) as well. As highlighted by Elferink and colleagues (2000), "Researchers have tried to define the vague concept of talent in studies… However, the suggestion that talent provides a basis for predicting excellence is not supported by the available evidence" (Elferink, Helsen, Hodges, VanWinkle, & Starkes, 2000, p. 487).

The findings from the present thesis support the conclusion that we are far from a common theoretical understanding of what comprises or predicts talent. This was evident in both studies as there was a tendency for the TID program to be operationalized by a discrete set of testing variables. This line of thinking rejects or ignores the concept that sport (and thus talent in sport) is complex, multidimensional and dynamic. Instead of scrutinizing skills and creating testing variables that have been measured in isolation of the sport context, a shift towards a more representative testing design is strongly encouraged. The use of these simple and discrete tasks have not been proven to be effective thus far, and therefore, should not continue to dominate popular discourse.

In addition to selection and de-selection, issues of continuation and discontinuation are central to TID in elite sport. While early identification appears an attractive avenue for sport organizations due to limited resources, it is potentially problematic for youth athletes. Recent research has drawn attention to the consequences of both selecting and de-selecting young athletes, most prominently discontinuation, attrition, burnout, or even withdrawal from sport (Bloom, 1985; Pion et al., 2015).

It has been proposed that young athletes who present 'potential' are streamlined to elite sport programs, which may negate proper athlete development. Pakhurst and Collins (2013) draw attention to young athletes who 'over commit' to a pathway that does not facilitate proper athletic development. Similarly, Pion and colleagues (2015) identified high rates of drop out among elite-level gymnasts, and speculated that the accumulation of physical and mental exhaustion that began at an early age led to premature dropout.

Further, there is evidence that sport organizations regularly test athletes before the age of puberty. While there are number of fundamental issues with this course of action, one of the most concerning is the impact this has on the development of young athletes. Perhaps most significantly, early identification and streaming of athletes leads to increasing focus on early participation and specialization in sport, a trend that carries a range of developmental and achievement-related consequences (Baker, Cobley & Fraser-Thomas, 2009). For instance, there is evidence that early entry and specialization in sport, can lead to potential of burnout and subsequently dropout from sport (Fraser-Thomas, Côté, & Deakin, 2008; Gould, Tuffey, Udrey, & Loehr, 1996; Malina, 2010; Wall & Côté, 2007, Wiersma, 2000). In order to mitigate these adverse effects, Brouwers et al., (2012) and Pion et al., (2015) suggest investment into early development programs instead of identification programs which may aid in the development of basic physical, motor and psychological characteristics that might prevent attrition from sport (Pion et al., 2015).

Another criticism of pre-pubertal testing is the lack of theoretical support for these decisions. Many of the qualities that distinguish top athletic performance in adults may not be apparent until late adolescence. Bloom and Sosniak (1995) indicated that a vast majority of adult competitive skills and abilities are not evident in young children. Since chronological age and biological maturity rarely progress at the same rate, children may be advantaged or disadvantaged, especially when comparing to chronological age norms (Vaeyens et al., 2008; Pearson, Naughton, & Torode, 2006). It is important that sport organizations consider these findings when trying to implement the most appropriate approaches for TID.

Previous research, alongside the findings of the two studies conducted in this project, certainly begs the question: is TID worth it? Davids and colleagues (2010) and Haymen and colleagues (2011) proposed that each higher performing athlete takes a unique developmental pathway to excellence (Phillips, Davids, Renshaw, & Portis, 2010; Haymen et al., 2011). While researchers have aimed to capture the stages of athlete development (see Bloom & Sosniak, 1985; Côté & Hay, 2002) these models have been criticized for assuming that the pathway to expert performance follows a linear trajectory. In reality, it is much more nuanced, influenced by many idiosyncrasies and cultural mediators. Therefore, finding a robust set of testing variables that can span sport and age domains may be an impossible task.

Despite these limitations, it is important to consider that TID programs are in their infancy. It is the responsibility of the researchers to help shape the future of TID in elite sport and push the boundaries of sport sciences. The following sections present some suggestions regarding how to improve TID in high performance sport.

Future directions: Greater use of longitudinal designs

In an attempt to filter out less-talented individuals, there has been a tendency for researchers and practitioners to compare different age groups and skill levels in cross-sectional designs (Breitback, Tug, & Simon, 2014). This approach appears to assume that characteristics of success can be extrapolated from performance at one point in time (Davids & Baker, 2007). It has been suggested that a shift from early (de)selection in cross-sectional designs and towards a focus on developmental opportunities should become a priority (Vaeyens et al., 2008). With this transition, a greater emphasis would be placed on the development of fundamental experiences. Moreover, 'developmental tracking' has been proposed as an alternative method to TID that may help mitigate some of the shortcomings of TID. This method is comprised of longitudinal monitoring and ongoing support and training, which may help to avoid Type I and Type II errors during (de)selection processes. Pinder and colleagues (2013) suggest that to understand the nature of talent, and conversely, talent wastage, future empirical work should seek to follow the career paths of successful and unsuccessful athletes in a comparative analysis. This type of longitudinal design would more likely provide opportunities to identify characteristics that are helpful in the development of successful senior athletes (Abbott & Collins, 2002). Another advantage of using longitudinal designs is that this approach avoids biases seen in retrospective designs and allows for determination of causality instead of correlation.

Inclusion of more representative designs

The notion of including a multidimensional testing design is not novel and the potential advantages of such an approach have been well documented in the literature (e.g., Abbott & Collins, 2004; MacNamara & Collins, 2011); however, TID continues to adopt a unidimensional approach in most cases (for exception see Elferink-Gemser et al., 2007; Falk et al., 2004; Figueiredo et al., 2009; Huijgen et al., 2013). It will be critical for future TID models to incorporate measures that better simulate the demands of competition in order to build more effective and accurate programs. Incorporating measures that reflect competition-specific demands may increase the predictive utility of TID programs. Importantly, studies should include a minimum of two different skilled/ talented groups in order to provide reasonable comparisons.

Incorporation of more diverse samples

It was evident from the findings in study 1 that there was a high degree of homogeneity within the studies' samples. It will be important for future research in TID to focus on areas that remain under-researched. For example, there appears to be a disparity in the amount of research examining elite-level females in TID programs. This could be particularly detrimental to the female population given the often unique developmental constraints of female systems versus male systems (e.g., under-funding, lower levels of public interest). There is insufficient evidence to show that the principles of TID in the elite male population (limited as they may be) can be applied to the elite female population. Using performance criteria based on male samples could result in the selection or de-selection of potentially talented female athletes. There appear to be distinct physical, physiological, and social differences between males and females (Drinkwater, 1984; Garhammer, 1991; Harbili, 2012; Hegge, Myhre, Welde, Holmberg, & Sanbakk, 2015; Knisel, Opitz, Wossmann, & Keteihuf, 2009; Matta, Oliver, Jagim, & Jones, 2016; Muad & Shultz, 1986; Sparling, 1980; Thomas, Kraemer, Spiering, Volek, Anderson, & Maresh, 2007), which should be taken into consideration in the context of TID.

In addition, there was an overrepresentation of studies utilizing samples of athletes from European countries and Australia. It would be naive to ignore the role of cultural and related differences in social systems that constrain opportunities for athlete development. Therefore, future research should look to a more international sample to understand how TID varies on a global scale (Green & Oakley, 2001).

Lastly, the findings from study 1 highlight an imbalance in research focussing on athletes under the age of 20. In many sports, the age of peak performance occurs much later than this age and, importantly, development does not end when athletes reaches adulthood. Future research should aim to incorporate older athletes to help understand how expert performance is maintained across the lifespan (Horton, Baker, & Schorer 2008). This may provide valuable insight into the pathways leading to longer career lengths as well as post-high performance career achievement (e.g., Masters level sport). Importantly, understanding predictors of long-term development in high performance sport would be useful for development of comprehensive models of holistic athlete development.

Concluding remarks

The two studies in this research project shed light on the surprisingly limited amount of literature on the efficacy of talent identification in sport, and aimed to contribute to the dearth of knowledge in the field. From the findings presented, it can be concluded that there remains a considerable amount that we have yet to learn in the realm of TID in elite-level sport.

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Table 1. Final selection of articles included in the review

Author	Sample Characteristics						Results
	Males			**Females**			
	N	**Age**	**Skill**	**N**	**Age**	**Skill**	
Barreiros et al., 2014	170	U16	Pre-Junior	27	U15	Pre-Junior	Only one third of the athletes who were selected to be top junior players were also selected to be on the senior team. This demonstrates the difficulty in using early identification as a predictor for future success.
	93	17-18	Junior	15	16-17	Junior	
	58	19+	Senior	6	18+	Senior	
	27	U16	Pre-Junior	64	U14	Pre-Junior	
	21	17-18	Junior	37	15-16	Junior	
	15	19+	Senior	21	17+	Senior	
	60	U16	Pre-Junior	15	U16	Pre-Junior	
	34	17-18	Junior	7	17-19	Junior	
	18	19+	Senior	3	20+	Senior	
	32	U16	Pre-Junior				
	12	17-19	Junior				
	9	20+	Senior				
Bottoni et al., 2011	66	14-18	Top World	N/A			The findings indicate that using retrospective analysis of running and

	15	14-18	Top Italian				swimming performance outcomes are not appropriate measures to use for the prediction of future triathlon success
Brouwers et al., 2012	1897	10-14	Youth	1624	10-14	Youth	Findings demonstrated that player performances' at young ages were not correlated with later success in tennis. Additionally, this study did not find an age which all players should start to perform in order to be successful at the professional level
	281	14	Professional	323	14	Professional	
	68	Open		60	Open		
	202	13-18	Junior	175	U18	Junior	
	68	14	Professional	60	14	Professional	
di Cagno et al., 2014	20	11.5 ± 0.5	Elite Cadets	N/A			Coordination and precision capabilities can be used as long-term predictors of success in gymnastics.
	21	13.3 ± 0.5	Junior Cadets				
	59	10.5 ± 0.5	Sub-elite Cadets				
Elferink-Gemser et al., 2007	15	16.0 ± 1.0	Elite	15	15.7 ± 1.0	Elite	Findings indicated that both female and male elite field hockey players scored better on technical and tactical variables. In addition, female elite-level athletes scored higher on interval endurance capacity and motivation compared to their sub-elite counterparts. Contrastingly, the males in the sub-elite category scored higher in motivation compared to their elite counterparts.
	17	16.4 ± 1.3	Sub-Elite	18	16.5 ± 1.1	Sub-Elite	
Falk et al., 2004	11	13.3 ± 0.7	Selected	N/A			Selected water polo players were

	13	13.7 ± 0.5	Non-Selected		superior on a variety of swimming and motor ability tasks, as well as in game intelligence.
Figueiredo, et al., 2009	63	11-14	Drop Out	N/A	Elite soccer players were found to be older, both chronologically and skeletally, larger, and they out preformed the sub-elite groups in physiological measures and motor skill tests. The degree of goal orientation did not differ between groups.
	90	11-14	Club		
	33	11-14	Elite		
Gil et al., 2007	29	U14	Selected	N/A	There were notable differences found among the U14 soccer players who were asked to play in the U15 team compared to the U14 players who were not selected. This selected group of athletes was found to be taller and heavier than their non-selected counterparts.
	19	U14	Non-Selected		
	36	U15	Selected		
	17	U15	Non-Selected		
	29	U16	Selected		
	12	U16	Non-Selected		
	32	U17	Selected		
	20	U17	Non-Selected		
Gil et al., 2014	64	9-10	Pre-Selection	N/A	The discriminant analysis showed that the selected soccer athletes were older, lighter, and had a lower body mass index rating. The selected individuals also performed better on the velocity
	21	9-10	Final Selection		

	34	9-10	Controls		and agility tests compared to the control and non-selected groups.
Gonaus & Müller, 2012	205	14	Drafted	N/A	Soccer players who were drafted demonstrated superior performance in sport-specific speed and power in the upper limbs as well as other physiological measures compared to non-drafted players.
	1160	14	Non-Drafted		
	252	15	Drafted		
	1089	15	Non-Drafted		
	228	16	Drafted		
	995	16	Non-Drafted		
	136	17	Drafted		
	668	17	Non-Drafted		
Huijgen et al., 2013	53	U12	Selected	N/A	Findings indicated that the Loughboorough Soccer Passing Test (LSPT) was able to distinguish between players who were selected compared to those who were de-selected.
	5	U12	De-Selected		
	46	U13	Selected		
	6	U13	De-Selected		
	44	U14	Selected		
	6	U14	De-Selected		
	37	U15	Selected		
	13	U15	De-Selected		
	26	U16	Selected		

	3	U16	De-Selected				
	31	U17	Selected				
	6	U17	De-Selected				
	21	U18	Selected				
	7	U18	De-Selected				
	11	U19	Selected				
	4	U19	De-Selected				
Lidor et al., 2005	29	12-13	Phase 1 Selected	20	12-13	Phase 1 Selected	The physiological and anthropometrical tests were not capable of discriminating between the selected and non-selected handball players. The only test that showed a difference between groups was the Slalom Dribbling test.
	118	12-13	Phase 1 Non-Selected	54	12-13	Phase 1 Non-Selected	
	24	12-13	Phase 2 Selected	20	12-13	Phase 2 Selected	
	109	12-13	Phase 2 Non-Selected	51	12-13	Phase 2 Non-Selected	
	18	12-13	Phase 3 Selected	N/A	12-13	Phase 3 Selected	
	24	12-13	Phase 3 Non-Selected	N/A	12-13	Phase 3 Non-Selected	
Pion et al., 2005	N/A			6	6-9	Survivors (Continued)	Only 18% of the gymnastics athletes who passed the baseline test consisting of motor skills and physiological measures continued performing at the highest level of competition five years later.
				85	6-9	Discontinued	

Pyne et al., 2005	105	N/A	Drafted	N/A	Findings showed that the 5m, 10m, 20m sprint, agility test, and the multi-stage shuttle run discriminated drafted athletes from non-drafted athletes. Of the drafted athletes, those who had better running vertical jump ability and faster agility scores were more likely to debut in an Australian Football League game. Anthropometric measures were not capable of discriminating between drafted versus non-drafted players or debuted players versus non-debuted players.
	78	N/A	Non-Drafted		
	166	N/A	Debuted		
	117	N/A	Non-Debuted		
Till et al., 2013	34	13.6 ± .2	Regional	N/A	There were significant main effects for selection level, but no significant differences were found for any individual variable to discriminate between selection levels for rugby league players
	19	13.6 ± .2	National		
	23	13.6 ± .2	National-Regional		
	5	13.6 ± .2	Regional - National		
Till et al., 2015	249	U15	Amateur	N/A	Findings illustrated that there were no significant differences between professional and academy rugby league players. There were, however, difference found between amateur players and professional players.
	261	U15	Academy		
	70	U15	Professional		
Till et al., in press	95	U13	Player Performance	N/A	Professional U14 and U15 rugby league players outperformed amateur

			Pathway		players on the sum of four skinfolds, speed, change of direction, speed and estimated VO2Max. Additionally, players who attained professional status were significantly more likely to be later maturing with lower body mass and reduced upper body power compared with amateur and academy players.
	50	U13	Amateur		
	45	U13	Academy		
	13	U13	Professional		
	195	U14	Player Performance Pathway		
	92	U14	Amateur		
	103	U14	Academy		
	18	U14	Professional		
	183	U15	Player Performance Pathway		
	107	U15	Amateur		
	183	U15	Academy		
	39	U15	Professional		
Van Yperen, et al., 2009	18	16.58 SD 1.4	Successful	N/A	There were no differences in levels of recorded exhaustion between the successful and the unsuccessful athletes. The, successful athletes reported higher engagement in problem-focused coping behaviour. The successful athletes were also more

	47	16.58 SD 1.4	Unsuccessful				likely to seek social support during stressful circumstances and rated their coaches as having a higher performance level. In terms of demographic and other social variables, successful athletes had more siblings, were more often of non-White ethnic origin and were more likely to have divorced parents.
Vestberg et al., 2012	14	25.3 SD 4.2	High Division	15	25.3 SD 4.2	High Division	For soccer athletes who were in the high division group, they out-performed their low division counterparts in general executive functioning tasks that are used to demonstrate creativity, response inhibition and cognitive flexibility skills.
	17	22.8 SD 4.1	Low Division	11	22.8 SD 4.1	Low Division	

Table 2. Frequency distribution of final studies included in the review

		N	%
Time Period of Publication			
	Jan 1990 – Dec 1994	0	0
	Jan 1995 – Dec 1999	0	0
	Jan 2000 – Dec 2004	1	5
	Jan 2005 – Dec 2009	6	30
	Jan 2010 – Dec 2015	11	55
	Jan 2015 – July 2015	2	10
Age			
	U10	3	15
	U20	15	75
	20+	1	5
	Not Specified	1	5
Sex			
	Female	2	10
	Male	13	65
	Female and Male	5	25
Sport			
	Australian Football	1	5
	Field Hockey	1	5
	Handball	1	5
	Gymnastics	3	15
	Rugby	3	15
	Soccer	7	35
	Tennis	1	5
	Triathlon	1	5

	Water Polo	1	5
	Mixed Sports	1	5
Outcome Measures			
	Cognitive/Psychological Capabilities	2	10
	Mixed Measurements	4	20
	Physical Profile	11	55
	Previous Performance	3	15
Terminology for 'Elite' Group			
	Drafted	2	10
	Elite Cadets	1	5
	Elite	3	15
	Final Selection	1	5
	High Division	1	5
	National	1	5
	Phase 3 Selected	1	5
	Professional	3	15
	Selected	3	15
	Senior	1	5
	Successful	1	5
	Survivors	1	5
	Top World	1	5

Table 3. Variables examined in the final analysis. Variables that did not have more than 20 unique entries for participants were excluded from the final analysis due to low statistical power.

Category of Testing Variables	**Variable Analyzed (>20 unique entries)**	**Athletes Represented**	**Significance**
Trackman			
	Ball Speed	30	
Physical Testing			
	Body Mass	21	
	Height	20	
	Balance R Foot Up	20	
	Balance L Foot Up	20	
	Core Front	20	
	Core Right	20	
	Core Left	20	No significant findings were identified for any variables
	Beep Test	20	
	2 Foot Sit and Reach	20	
	L Foot Sit and Reach	20	
	R Foot Sit and Reach	20	
	Squat Jump	33	
	Squat Jump Right	21	
	Squat Jump Left	21	
	Med Ball Throw	21	
	Pull Up	21	
	Push Up	21	
	Grip Strength Left	21	
	Grip Strength Right	21	

Handicap and Ranking		
	Tournament Handicap	22
	World Ranking	31
Uncommon Golf and Short Game		
	Overall Handicap	21
Tournament Report		
	Round Score 1 *	39
	Round Score 2 *	39

Table 4. Overview of variables tracked by Golf Canada and number of variables used for analysis.

Category of Testing Variables	Variables Examined	Variables Excluded	Variables Analyzed
Trackman	40	39	1
Trackman Combine	10	10	0
Flight Scope	16	16	0
Physical Testing	40	21	19
Physical Testing Jason Glass	43	43	0
Handicap and World Ranking	7	5	2
SAM Puttlab	20	20	0
Uncommon Golf and Short Game	15	14	1
Beep Test	3	3	0
Tournament Ranking	12	10	2

Table 5. Detailed descriptions of the testing categories employed by CG

Category of Variables	Description	Example of Variable
Trackman	A golf simulator program that measures swing elements using radar technology and translates it into automatic feedback	• Ball Speed • Club Speed
Trackman Combine	In addition to Trackman, providing a cumulative score for all testing variables from Trackman data.	• Cumulative Score
Flightscope *	Same principle as Trackman	• Ball Speed • Club Speed
Physical Testing	A battery of tests that are used to assess the anthropometric and physical profile of golfers	• Height • Weight • Squat Jump • Grip Test
Physical Testing-Jason Glass **	A subjective measure of physical strength and movement patterns performed by Jason Glass, Golf Team Canada's Strength and Conditioning Coach.	• Functional Movement Assessment
Handicap & Ranking	A cumulative ranking number given to athletes based on their handicap (a number calculated based on the degree of difficulty of the course and the player's associated score after a tournament) and world ranking, based tournament performance from international competition.	• Handicap • World Ranking
SAM Puttlab*	An analysis and training system, which utilizes ultrasound measurements to record and provide feedback on putting movements.	• Clubface at impact • Putter path direction
Uncommon Golf & Short Game	This testing battery requires the athlete to perform a series of challenging shots. If the golfer is within a certain range of the hole, he/she will be given a corresponding score.	• Pitch Shot • Bunker Shot
Beep Test	A test used to measure the aerobic fitness of an athlete. The test requires an athlete to run lengths of a 20m distance between a series of sounds (beeps)	• Beep Test
Tournament Round Performance	A round score is recoded (typically 4) for each tournament the athlete attends.	• Round Score

*Not included due to lack of data
**Not included due to subjectivity of testing measures

Table 6. Suggested tests and measurement protocol for future TID program

Focus	Measurement Tool	Original Source	Variables Examined	Supported in the literature for application to elite sport
Goal Orientation	Task and Ego Orientation in Sport Questionnaire	Chi & Duda, 1995; Duda, 1998	Task Mindset Goal Mindset	Figuierdo, et al., 2009
Psychological	Psychological Skills Inventory for Sports (PSIS)	Mahony, Gabriel & Perkins 1987	Motivation Confidence Anxiety Mental preparation Team emphasis Concentration	Companjen & Bakker, 2003; Elferink, et al., 2007; Li, 1999; Pelletier, Fortier, Vallerand, Tuson, Briere, & Blais, 1995; Roberts & Treasure, 2001
Training History	The developmental History of Athletes Questionnaire (DHAQ)	Hopwood, MacMahon, Baker, & Farrow, 2010	Deliberate practice	Baker, Côté, & Deakin, 2005; Gould, 2010; Macnamara, Hamrick, Oswald, 2014; Malina, 2010; Wisersma, 2000
			Deliberate play	Baker, 2003; Baker, Côté, & Abernethy, 2003; Baker et al., 2005; Berry, Abernethy, & Côté 2008; Côté, Horton, MacDonald, & Wikes, 2009; Forsman,

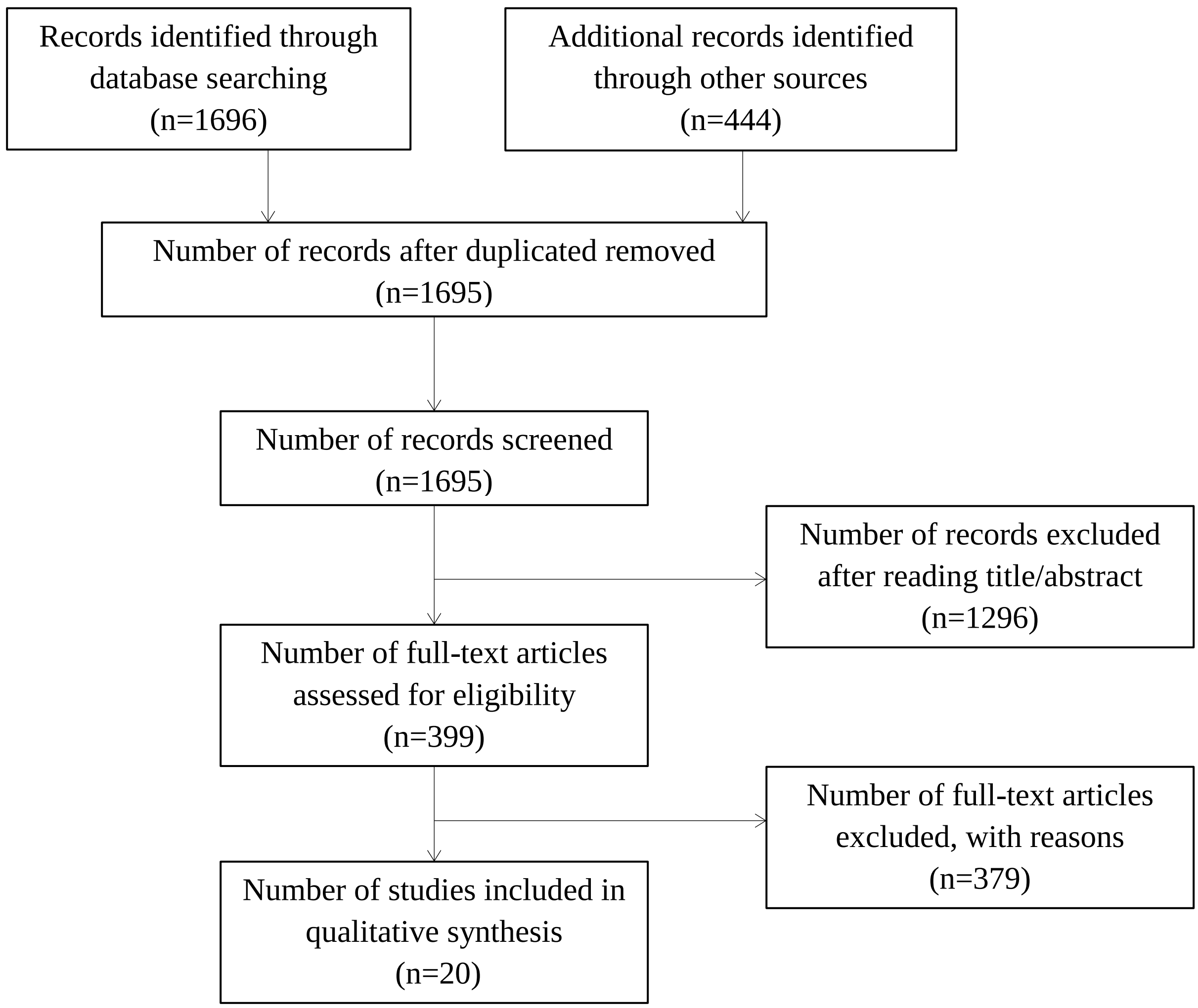
				Blomqvist, Davids et al., 2016; Fraser-Thomas et al., 2008; Johnson, Tenenbaum, Edmonds, & Castillo, 2008
			Birth Date	Baker, Schorer, Cobley, Schimmer, & Wattie, 2009; Bruner, Macdonald, & Pikett, 2011; Deaner, Lowen, & Cobley, 2013; Handcock, Alder, Côté, 2013; Handcock, Starkes, & Ste-Marie, 2015; Ishagami, 2016; Schorer, Wattie, & Baker, 2013; Wattie, Baker, Cobley, & Montelpare, 2007; Wattie, Cobley, & Baker, 2008; Wattie, Shorer, & Baker, 2015
			Birth Place	Baker & Logan, 2007; Côté, MacDonald, Baker & Abernethy, 2006; Hayman et al., 2014, MacDonald, King, Côté et al., 2009

The Role of the Family	DHAQ	Hopwood, MacMahon, Baker, & Farrow, 2011	Relationship between athlete and mother and father/ guardian, Education of the mother/father/guardian Mother/father/ guardian's participation in sport	Côté et al., 1999; Durand-Bush & Salmela, 2002; Fredricks, & Eccles, 2005; Gould, Diefffenbach, & Moffett, 2002; Gould, Lauer, Rolo, Hannes, & Pennisi, 2010; Hayman et al., 2011; Holt, Tamminen, Black, Sehn, & Wall, 2008;Keegan, Spray, Harwood, & Lavellee, 2010; Vernacchia, McGyure, Reardon, & Templin, 2000
Performance Milestones	DHAQ	Hopwood, MacMahon, Baker, & Farrow, 2012	Highest level of competition	Bruce, Farrow, & Raynor, 2013; Elferink- Gemser, Visscher, Lemmink et al., 2007; Hayman et al., 2011; Vaeyens, Gullich, Warr, & Philippaerts, 2009
The role of the coach	DHAQ	Hopwood, MacMahon, Baker, & Farrow, 2014	Hours spent with a coach or specialized instructor	Hill & Sotiriadou, 2016; Macquet, & Stanton, 2014
Quiet Eye/ Gaze Behaviour	Applied Science Laboratories (ASL) Mobile	Moore, Vine, Cook, Ring & Wilson, 2012	N/A	Dicks, Button, & Davids, 2010; Fischer, Reinhoff, Tirp et al., 2015; Martell & Vickers,

	Eye Tracker			2004; Vickers & Williams, 2007; Ryu, Abernethy, Mann, Poolton, & Gorman, 2013
Reading the Game	In Progress	In Progress	N/A	Lidor, Falk, Arnon et al., 2005; Nideffer, Sagal, Lowry et al., 2001; Singer, 2000
Decision Making	In Progress	In Progress	N/A	Baker, Côté & Abernethy, 2003; Ryu, Abernethy, Mann et al., 2013
Game Intelligence	In Progress	In Progress	N/A	Falk, Lidor, Lander et al., 2004
Imagery	The Motivational Imagery Ability Measure for Sport (MIAMS) Vividness of Movement Imagery Questionnaire (VIMQ-2)	Roberts et al., 2008	N/A	Cummings & Hall, 2002; Frey & Ravissa, 2003; Greg & Hall, 2006, Greg Jenny, & Hall, 2016, Salmon, Hall, & Haslam, 1994
Emotional Intelligence	Emotional Intelligence Questionnaire (EIQ)	Schuttle et al., 1998	N/A	Laborde, Dosseville, & Allen, 2015; Wangstaff, Fletcher, & Hanton, 2012
Coping Strategies	In Progress	In Progress	N/A	Nicholls & Polman, 2007; Puente-Diaz &

				Anshel, 2005
Grit	In progress	In Progress	N/A	Larkin, O'Connor, & Williams, 2016;
Self-Regulation	In Progress	In Progress	N/A	Pelletier, Fortier, Vallerand, & Briere, 2001
Goal Orientation	Perceptions of Success Questionnaire (POSQ)	Roberts, Treasure & Balague, 1998	N/A	Greg, Jenny & Hall, 2016

Figure 1. PRISMA flow chart showing number of records collected and number of eligible records after screening process



Appendix A. Additional list of variables from Table 1

Author	**Sport**	**Origin of Sample**	**Length of Study**
Barreiros et al., 2014	Soccer Volleyball Swimming judo	Portugal	3+ years
Bottoni et al., 2011	Triathlon	Italy	4 + years
Brouwers et al., 2012	Tennis	Unknown	16+ years
di Cagno et al., 2014	Gymnastics	Italy	3+ years
Elferink-Gemser et al., 2007	Field Hockey	Netherlands	3+ years
Falk et al., 2004	Water Polo	Israel	2+ years
Figueiredo, et al., 2009	Soccer	Portugal	2+ years
Gil et al., 2007	Soccer	Spain	1 Season*
Gil et al., 2014	Soccer	Unknown	1+ years
Gonaus & Müller, 2012	Soccer	Austria	9+ years
Huijgen et al., 2013	Soccer	Netherlands	3+ years
Lidor et al., 2005	Handball	Israel	3+ years
Pion et al., 2005	Gymnastics	Belgium	5+ years
Pyne et al., 2005	Australian Football League	Australia	7+ years
Till et al., 2013	Rugby League	UK	2+ years

	Players		
Till et al., 2015	Rugby League	UK	2+ years
Till et al., in press	Rugby League	UK	7+ years
Vandrope et al., 2012	Gymnastics	Belgium	2+ years
Van Yperen, et al., 2009	Soccer	Netherlands	15 years
Vestberg et al., 2012	Soccer	Sweden	2+ years

* Study did not specify the length of a season so it was assumed that it was the course of a year.

Appendix B. List of variables included in the Golf Canada dataset

Category of Test	Variable Examined
Trackman	Time and date
	Wind
	Temperature
	Altitude
	Humidity
	Ground Type
	Pressure
	Shot Number
	TMD Number
	Club
	Ball
	Club Speed
	Angle of Attack
	Club Path
	Vertical Swing Plane
	Horizontal Swing Plane
	Dynamic Loft
	Face Angle
	Ball Speed
	Smash Factor
	Vertical Angle
	Horizontal Angle
	Spin Rate
	Spine Rate Type
	Spin Axis

	Max Distance Max Height Max Side Last Data Length Last Data Slide Last Data Height Last Data Time Carry Length Carry Slide Carry Vertical Angle Carry Ball Speed Carry Flight Time Total Flat Length Total Flat Slide Used In Stat
Trackman Combine	Time and Date Target Points Distance Percentile Rank Best Average 90^{th} Percentile 75^{th} Percentile 50^{th} Percentile
Flight Scope	Time and Date Carry Distance

	Total Distance Lateral Distance Club Speed Ball Speed Smash Efficiency DCORE Efficiency Backspin Sidespin Launch Vertical Launch Horizontal Descent Height Flight Classification
Physical Testing	Time and Date Mass Height Sitting Height Arm Length Balance Right Heel Up Balance Left Heel Up Balance Right Eye Closed Balance Left Eye Closed Core Front Core Right Core Left Beep Test

	2 Foot Sit and Reach Right Foot Sit and Reach Left Foot Sit and Reach Squat Jump Squat Jump Right Squat Jump Left Countermovement Jump Countermovement Jump Right Countermovement Jump Left Med Ball Throw Sit Up Push Up Grip Strength Right Grip Strength Left Shuttle Run VO2 Max Subscap Tricep Chest MidAx Ab MTHI Bicep Mcalf Supraillium HCT HB

Physical Testing – Jason Glass	Time and Date Overall-Start Overall- Finish Overall- Difference Overall – My Expectations Overall Reality Function Start Function Finnish Function Difference Function My Expectation Function Reality Strength/Power Start Strength/Power Finish Strength/Power Difference Strength/Power My Expectations Strength/ Power Reality Vertical Jump Start Vertical Jump Finish Vertical Jump Difference Vertical Jump My Expectations Vertical Jump Reality Chest Pass Start Chest Pass Finish Chest Pass Difference Chest Pass My Expectations Chest Pass Reality Sit Up and Throw Start

	Sit Up and Throw Finish Sit Up and Throw Difference Sit Up and Throw My Expectations Sit Up and Throw Reality Rational Throw Start Rational Throw Finish Rational Throw Difference Rational Throw My Expectations Rational Throw Reality Push Up Stability Start Push Up Stability Finish Push Up Stability Difference Push Up Stability My Expectations Push Up Stability Reality Improvement Recommendations
Handicap and Ranking	Time and Date Tournament Handicap World Ranking GCOOM Jr Rank GCOOM Snr Rank PAOOM Jr Rank PAOOM Snr Rank
SAM Puttlab	Time and Date Project Face at Aim Face at Aim Score

	Face at Aim Consistency Face at Impact Face at Impact Score Face at Impact Consistency Club Head Rotation Start Club Head Rotation Impact Club Head Rotation End Club Head Rotation Score Club Head Rotation Consistency Rotation at Impact Putter Path Direction Impact Spot Impact Spot Score Impact Spot Consistency Rise Angle at Impact Shaft Angle at Impact
Uncommon Golf and Short Game	Time and Date Bunker Shot Bunker Handicap Wedge Shot Wedge Handicap Chip Shot Chip Handicap Pitch Shot Pitch Handicap Lag Putting Lag Putting Handicap

	Putting Skills Putting Skills Handicap Total Points Overall Handicap
Beep Test	Time and Date Level Score
Tournament Reports	Time and Date Tournament Location Course Par Rating Finish Result Score Round 1 Score Round 2 Score Round 3 Score Round 4 Total Score / Result